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ORIGINAL RESEARCH

A NEW CLINICAL MUSCLE FUNCTION TEST FOR ASSESSMENT OF HIP EXTERNAL ROTATION STRENGTH: AUGUSTSSON STRENGTH TEST

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ABSTRACT

Introduction: Dynamic clinical tests of hip strength applicable on patients, non–athletes and athletes alike, are lacking. The aim of this study was therefore to develop and evaluate the reliability of a dynamic muscle function test of hip external rotation strength, using a novel device. A second aim was to determine if gender differences exist in absolute and relative hip strength using the new test.

Methods: Fifty–three healthy sport science students (34 women and 19 men) were tested for hip external rotation strength using a device that consisted of a strap connected in series with an elastic resistance band loop, and a measuring tape connected in parallel with the elastic resistance band. The test was carried out with the subject side lying, positioned in 45° of hip flexion and the knees flexed to 90° with the device firmly fastened proximally across the knees. The subject then exerted maximal concentric hip external rotation force against the device thereby extending the elastic resistance band. The displacement achieved by the subject was documented by the tape measure and the corresponding force production was calculated. Both right and left hip strength was measured. Fifteen of the subjects were tested on repeated occasions to evaluate test–retest reliability.

Results: No significant test–retest differences were observed. Intra–class correlation coefficients ranged 0.93–0.94 and coefficients of variation 2.76–4.60%. In absolute values, men were significantly stronger in hip external rotation than women (right side 13.2 vs 11.0 kg, $p = 0.001$, left side 13.2 vs 11.5 kg, $p = 0.002$). There were no significant differences in hip external rotation strength normalized for body weight (BW) between men and women (right side 0.17 kg/BW vs 0.17 kg/BW, $p = 0.675$, left side 0.17 kg/BW vs 0.18 kg/BW, $p = 0.156$).

Conclusions: The new muscle function test showed high reliability and thus could be useful for measuring dynamic hip external rotation strength in patients, non–athletes and athletes. The test is practical and easy to perform in any setting and could therefore provide additional information to the common clinical hip examination, in the rehabilitation or research setting, as well as when conducting on–the–field testing in sports.

Level of evidence: 3

Keywords: Dynamic test, hip external rotation, muscle strength, reliability

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INTRODUCTION

Adequate hip strength is important throughout life. The ability of the elderly individual to perform chair rises and stair and level walking, for example, is dependent on sufficient levels of hip strength.[1] Also, hip strength is important to a wide range of athletic and sporting activities (e.g., soccer, gymnastics, weight lifting).[2] Moreover, impaired hip muscle strength – particularly of the hip external rotators and abductors – have been associated with various musculoskeletal disorders, both in the hip region, such as femoroacetabular impingement (FAI),[3] as well as distal to the hip (patellofemoral pain and iliotibial band syndrome, for example).[4,5] Additionally, the role of hip strength in the etiology of anterior cruciate ligament (ACL) injuries has received increased attention in recent years.[6,7] In a recent prospective study, hip external rotation and abduction strength were found to be significantly lower in ACL injured athletes compared with noninjured athletes.[8] The authors concluded that measures of preseason hip abduction and external rotation strength independently predicted future ACL injury status in competitive female and male athletes.[8] Also, studies have reported deficits in isokinetic hip strength following ACL reconstruction.[9-14] Further, several studies have been performed on gender differences in the relationship between hip strength and lower extremity injuries over the past decade.[15-17] Taken together, information about hip muscle performance through strength testing is of paramount importance in orthopedic practice, sports medicine, sports, as well as in research.

When it comes to clinical tests of hip strength, no particular type of test could be considered as the gold standard measure. Manual hip muscle strength testing is commonly used for the assessment of muscle strength. In the absence of severe weakness, however, it is relatively inaccurate and unreliable.[18] Further, isometric handheld dynamometry is used as an assessment tool in the clinic and also in research for the measurement of hip strength.[19] This test method may have drawbacks in terms of difficulties to accurately maintain the placement of the dynamometer, and at the same time stabilize the subject. This is especially true when the "break test" procedure is used, where the examiner applies resistance, trying to force the hip to "break" its hold.[20] Further, it was recently noted that isometric hip strength assessment using handheld dynamometry was subject to intertester bias when testers were of different sex and strength.[21] Taken together, there appears to be a lack of clinical muscle function tests that measure hip strength dynamically and, furthermore, where the examiner is not directly involved, i.e., applies resistance. Since most physical activity during work, sports and leisure time is dynamic in its nature, dynamic strength tests could seem to be more valid than isometric ones. The aim of this study was therefore to develop and evaluate the reliability of a dynamic muscle function test of hip external rotation strength, using a novel device. A second aim was to determine gender differences in absolute and relative hip strength using the new test.

METHODS

Subjects

Fifty–three sport science students (34 women and 19 men) volunteered to participate in the study. Table 1 displays the subject demographics. All subjects were healthy and active in various sports training, on either a recreational or competitive level, with asymptomatic back, hip and knee function. Subjects that reported any musculoskeletal disorders of the trunk or lower extremities, or any neurological conditions were excluded. Information regarding the study was given to all subjects and informed consent was obtained. Approval for the study was granted from the Regional Ethics Committee.

Development of the test device

A device was developed that consisted of a strap (Arno, Sweden) connected in series with an elastic resistance band loop (model medium rubber band, Refit, Sweden), and a measuring tape, cut off at 50 cm length (model 150 cm, Profi, Germany) connected in parallel with the elastic resistance band (Figure 1). Using the trial and error method

Table 1. *Descriptive Statistics.*

	Women (±SD)	Men (±SD)
Number of subjects	34	19
Age (years)	23 (±3)	24 (±3)
Body mass (kg)	66 (±10)	78 (±12)
Height (cm)	170 (±7)	184 (±10)

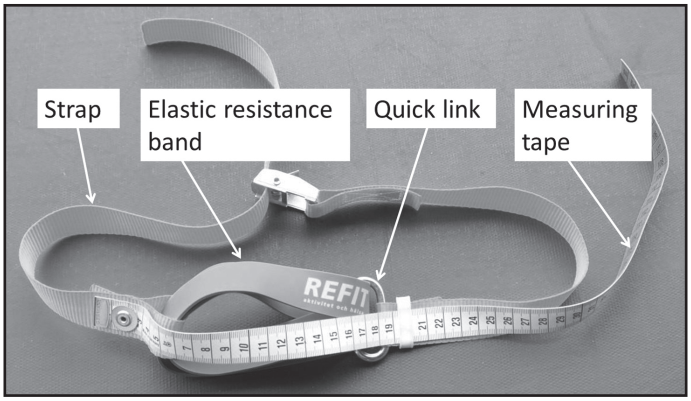

Figure 1. *The test device consisted of a strap, an elastic resistance band and a measuring tape.*

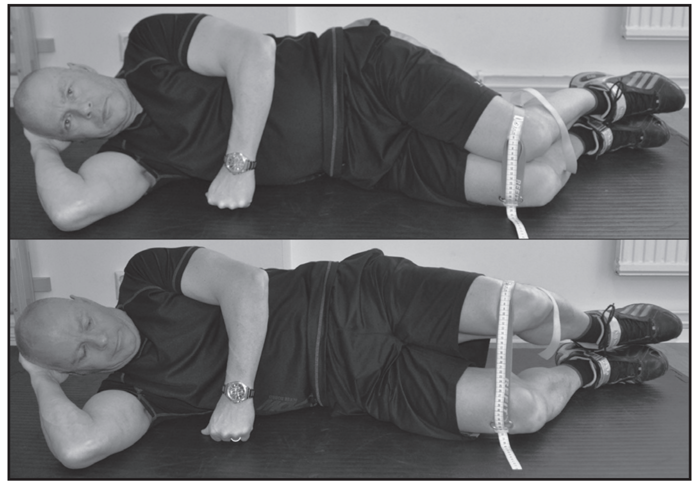

Figure 3. *Testing setup: The test was carried out with the subject side lying, with the device firmly fastened proximally across the knees. The subject then exerted maximal concentric hip external rotation force against the device, thereby extending the elastic resistance band. The displacement achieved by the subject was documented by the tape measure. Upper panel: Starting position. Lower panel: End position.*

for solving problems, the elastic resistance band loop was doubled for appropriate resistance and proper length (approximately 14 cm). The strap was attached to the elastic resistance band with a quick link (Swedol, Sweden). The first part of the measuring tape was permanently fastened on the strap on one side of the rubber band, using a rivet. The middle part of the measuring tape was attached to the strap on the other side of the rubber band with a clip so that it could run along the strap, as the rubber band extended.

Experimental set–up

The test was carried out with the subject side lying, positioned in 45° of hip flexion and the knees flexed to 90°, with the device firmly fastened proximally across the knees. The subject's shoulders, hips and feet were aligned (Figure 2). With the top leg, the subject then exerted maximal hip external rotation force against the device, thereby extending the elastic resistance band (Figure 3). The displacement achieved by the subject was documented in mm by the tape measure. Both right and left hip strength was measured, and the test administered in random order to each subject. One practice trial and two experimental trials with one minute of rest between trials were performed. The best value of the two experimental trials was recorded. Before the testing session, each subject performed a five minute warm–up that incorporated movements for the lower extremity including squats, forward lunges, lateral squats and toe raises. All hip strength measurements were obtained by a single examiner, a physical therapist that had 25 years of experience of muscle strength testing. Because of logistical factors, the examiner conducting the test was not blinded as regards to the results of the test.

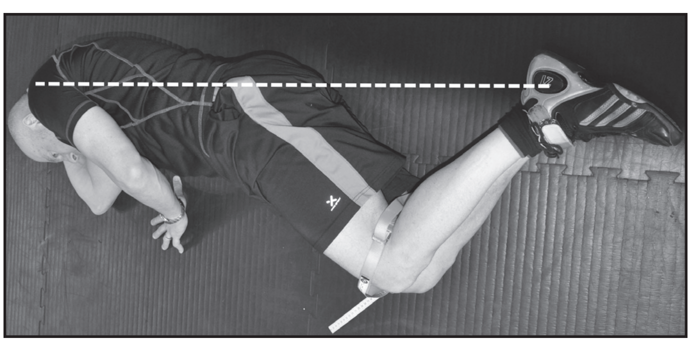

Figure 2. *Testing setup: The subject's shoulders, hips and feet were aligned with the knees at 90º of flexion.*

Conversion of elastic resistance band displacement to force

The extension of an elastic resistance band is proportional to the force, thus there is a linear relationship between the applied force and the resulting extension, known as Hooke's law.[22] Thus in order to investigate the corresponding force production, based on the distance achieved by the subjects, the elastic resistance band loop was hanged from a stand. At the lower end a 5 kg weight plate (Eurosport Fitness, Sweden) was placed and the length of the rubber band was measured using the tape measure. More weight plates were then added in increments of 2.5 kg. The starting weight (5 kg) resulted in less displacement than what the weakest of the subjects achieved and the end weight was 17.5 kg which resulted in slightly greater displacement than the result of the strongest subject. A load-versus-displacement plot showed a strong linear relationship, i.e. the increase in length corresponded to a progressive increase in the elastic resistance. Using the plot, it was possible to return interpolated results for any given value.

Test occasions

Fifteen of the subjects (10 women and five men) were tested on repeated occasions (seven days apart) to evaluate test–retest reliability. All testing of the subjects was performed using the same procedure for both occasions.

Statistical methods

The results are presented as means with SDs. To estimate the test–retest reliability of the test of hip strength, intraclass correlation coefficient (ICC)[23] with the two–way random effects model of the measurements with 95% confidence interval (CI) were used. Further, within–subject variation was determined using typical error expressed as a coefficient of variation (CV).[24] A paired samples t–test was used to detect significant test–retest differences. Differences in performance between the women and the men for the test of hip strength were analyzed using independent–samples t–test. The significance level was set at $p < 0.05$.

RESULTS

Descriptive characteristics of the subjects are presented in Table 1. The hip external rotation strength test results on the different test occasions are presented in Table 2. No significant test–retest differences were observed in the scores of the subjects that were tested on repeated occasions (right side 11.9 $\pm$ 2.2 vs 12.1 $\pm$ 2.3 kg, $p = 0.126$, left side 11.7 $\pm$ 2.1 vs 12.2 $\pm$ 2.4 kg, $p = 0.109$). ICCs ranged 0.93–0.94, CIs 0.80–0.98 and CVs 2.76–4.60%. Gender differences in hip strength are shown in Table 3. In absolute values, men were on average significantly stronger in hip external rotation than women (right side 13.2 $\pm$ 1.7 vs 11.0 $\pm$ 2.0 kg, $p = 0.001$, left side 13.2 $\pm$ 1.4 vs 11.5 $\pm$ 2.0 kg, $p = 0.002$). On average, there were no significant differences in hip external rotation strength normalized to body weight (BW) between men and women (right side 0.17 $\pm$ 0.02 kg/BW vs 0.17 $\pm$ 0.03 kg/BW, $p = 0.675$, left side 0.17 $\pm$ 0.02 kg/BW vs 0.18 $\pm$ 0.03 kg/BW, $p = 0.156$).

Table 2. *Hip External Rotation Strength Test Results in Kilograms for the Right and Left Side on the Different Test Occasions (n = 15). Expressed as Mean (± SD).*

	Right side	Left side
1st test	11.9 (±2.2)	11.7 (±2.1)
2nd test	12.1 (±2.3)	12.2 (±2.4)
ICC	0.94	0.93
95% CI	0.80–0.98	0.81–0.98
CV (%)	2.76	4.60
P-value	0.126	0.109

Abbreviations: SD, standard deviation; ICC, intraclass correlation coefficient; CV, coefficient of variation

DISCUSSION

The main findings of this study were that the new clinical muscle function test for assessment of dynamic hip external rotation strength showed high reliability and proved to be applicable on young healthy subjects, active in various sports training, on either a recreational or competitive level. In clinical practice, reliable evaluation tools that measure dynamic hip strength have been lacking. In this study a novel way to measure muscle strength in the hip using an elastic resistance band loop and a measuring tape was therefore developed. The test can be readily used for example by an orthopaedist or a physiotherapist in the clinic, or an athletic trainer

Table 3. *Gender Differences in Hip Strength. Expressed as Mean (± SD).*

Variable	Women				Men			
	Right side		Left side		Right side		Left side	
	Absolute (kg)	Relative (kg/BW)	Absolute (kg)	Relative (kg/BW)	Absolute (kg)	Relative (kg/BW)	Absolute (kg)	Relative (kg/BW)
HER	11.0 (±2.0)	0.17 (±0.03)	11.5 (±2.0)	0.18 (± 0.03)	13.2 (±1.7)*	0.17 (±0.02)	13.2 (±1.4)*	0.17 (±0.02)

*Different from women, p<.05.
Abbreviations: SD, standard variation; BW, body weight; HER, hip external rotation

or a strength and conditioning coach in a gym, as it is simple, non-expensive and does not require laboratory equipment. Further, this quick and easy test could be systematically implemented in different research projects allowing for large groups of athletes and patients to be followed prospectively. This would in turn improve the possibilities to answer questions such as the effect of strength training during FAI–rehabilitation and the role of hip muscle strength in the etiology of ACL injuries. Also, the new hip external rotation strength test could be used as a complement to the common strength tests (e.g., thigh muscle strength tests) performed before return to sport after ACL reconstruction.

Studies have been performed on the properties of elastic bands used in exercise programs,[25-27] noting that elastic rubber bands provide consistent, linear, and predictable increase in force with elongation. In the present study, all subjects were measured using the same rubber band. Because the rubber band was doubled and of a heavy–duty type it was only moderately stretched during testing. Therefore, the amount of degradation to the rubber band compound was probably negligible. A rubber band will, however, change its mechanical properties over time especially if heavily used. So for purposes of testing it should be replaced on a regular basis. It is also important to choose a rubber band that is strong enough to be only moderately and not maximally stretched during testing, thereby extending the band's longevity and precision.

Researchers, orthopedists, physiotherapists and strength and conditioning coaches have a variety of modes available for strength testing.[28] Strength testing using elastic bands seems to fall into the isotonic category even though the resistance is not constant. The isotonic subcategory term 'variable resistance' is used when the resistance throughout the range of motion is varied, for example by an irregularly shaped camwheel or a lever arm.[29] This definition – 'isotonic variable resistance' – would apply also for rubber bands where the level of resistance varies according to the force/extension relationship.

Values of reliability for the isotonic, variable resistance hip muscle function test were high (ICC 0.93–0.94 with narrow CIs, CV 2.76–4.60%) and of the same order of magnitude or higher as those for isokinetic[30] (ICCs ranging from 0.55 to 0.76) and isometric[21] (ICCs ranging from 0.82-0.91) modes of hip strength testing. In clinical practice and when conducting on–the–field testing in sports the new dynamic hip strength test might therefore be the preferred choice over isokinetic or isometric measurements.

Although it was not the main aim of the study, gender differences in hip strength were analyzed using both absolute and body weight normalized strength data to compare strength differences between women and men. In the present study, the women displayed 85% of the men's absolute hip strength. There were, however, no significant differences in mean hip external rotation strength normalized for body weight between men and women. This result is in contrast with Cowan and Crossley[31] who observed lower hip external rotation strength relative to body weight in young and healthy females compared with males. A possible explanation for this contradictory finding is that the subjects' isometric rather than isotonic strength was measured in the study by Cowan and Crossley.[31]

The relatively large sample size is a strength of this study, and the high reliability values for the test are encouraging. The generalizability of the present study, however, is limited to healthy, active young adults. Further studies on e.g., patients with different knee and hip injuries, using the newly developed muscle function test of dynamic hip external rotation strength, are therefore desirable. Also, the question of the validity of the new measurement should be addressed. A criterion validity test comparing the new device with "gold standard" would have been desirable. However, no isotonic "gold standard" test of hip strength exists today in the clinical setting. When it comes to the movement of the new test and the position of the subject, it is identical to the so called Clam exercise in which the subject is in sidelying with both legs flexed to 45° at the hip and 90° at the knee, typically with an elastic rubber band around the thighs to provide resistance. In a recent study that assessed which hip exercises are best for activating the gluteal muscles, Selkowitz et al.[32] noted that gluteal muscle activation (especially the gluteus maximus) was among the highest during the Clam exercise. This in turn validates the new test of hip strength, in that it actually measures the strength of the hip muscles.

In a paper on closed and open kinetic chain tests of muscle strength, Augustsson and Thomeé[33] stated that the purpose of assessment should determine which mode of test be used: to identify specific deficiencies or problem areas, open kinetic chain testing would be preferred, whereas a closed kinetic chain test may be better suited for assessing functional performance. In the present study, the test comprised of a side lying hip external rotation motion performed in an open kinetic chain. Because of its "non-functional" nature, it is not clear how the test corresponds to dynamic weight bearing movement performed in a closed kinetic chain. Strength measured such as in the present study, however, is able to isolate a specific muscle or muscle group and would therefore be the preferred choice as a diagnostic test of muscle function.

CONCLUSION

The novel muscle function test of dynamic hip external rotation strength showed high reliability and could be a useful device for measuring strength in different populations (e.g., athletes and patients) for both clinical and research purposes. Furthermore, the test is cost effective, easy to use, and could provide additional information to the common clinical hip examination as well as when conducting on–the–field testing in sports.

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